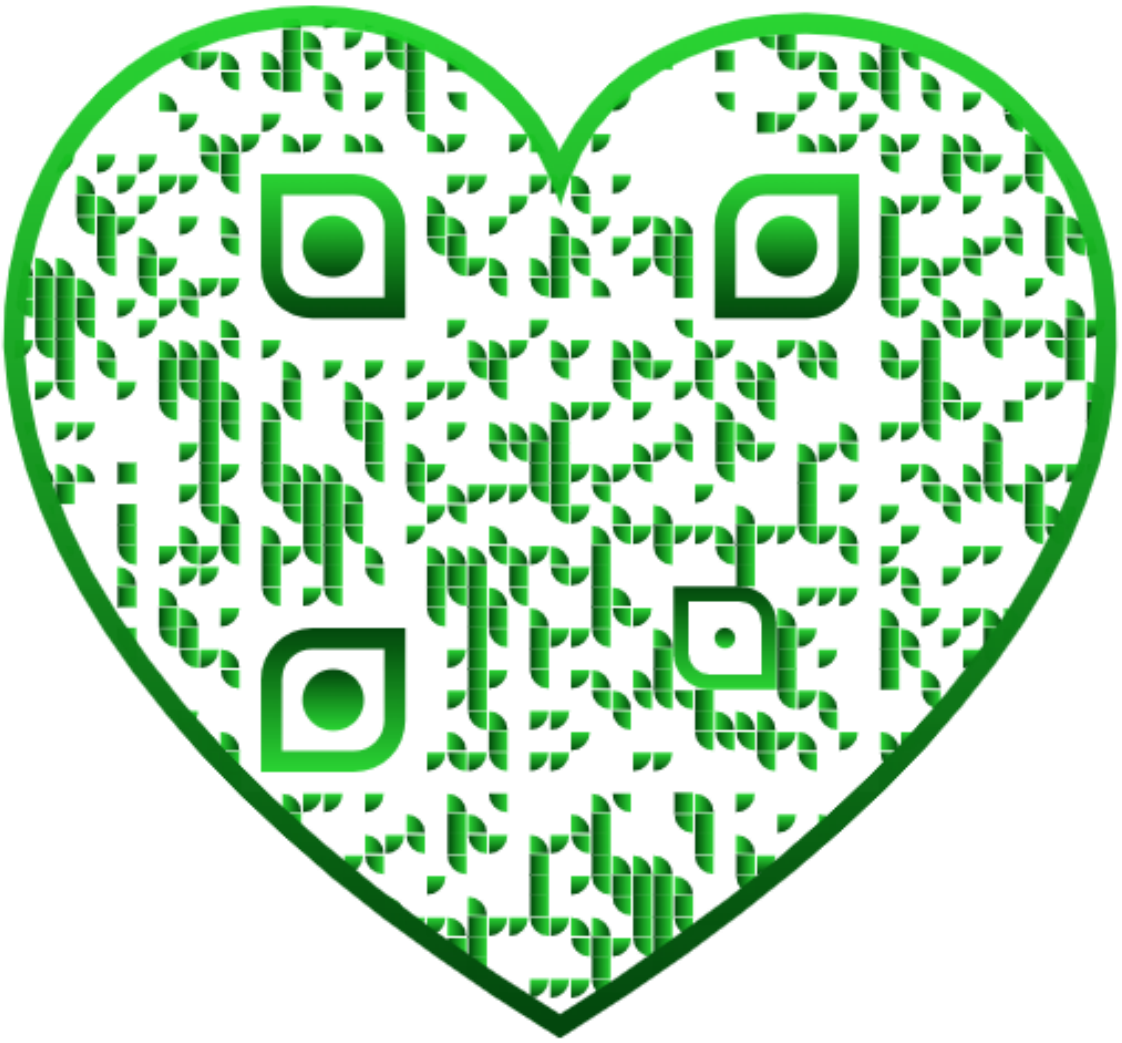
SECTION 8

Infection Prevention and Control



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CHAPTER

Surgical Site Infections and Antimicrobial Prophylaxis

Laxman G Jessani

INTRODUCTION

Among healthcare-associated infections, surgical site infection (SSI) is the most common following surgery. Not only is significant morbidity and mortality associated, but it also involves associated hospitalization, transfer to a critical care unit, and hospital readmission.[1]

DEFINITIONS

The most widely used definition of SSI is provided by the Centers for Disease Control and Prevention (CDC). SSI is defined as an infection related to a surgical procedure that occurs at the surgical site within 30 days following surgery (or up to 90 days after surgery if an implant is involved).[2] Incisional SSIs are further classified as those involving only skin and subcutaneous tissues (superficial incisional SSIs) and those involving deeper, softer tissues of the incision (deep incisional SSIs) (Figure 1 and Table 1). Organ/space infections are deep infections and include abscesses, anastomotic leaks from intra-abdominal operations, and implant-associated infections.

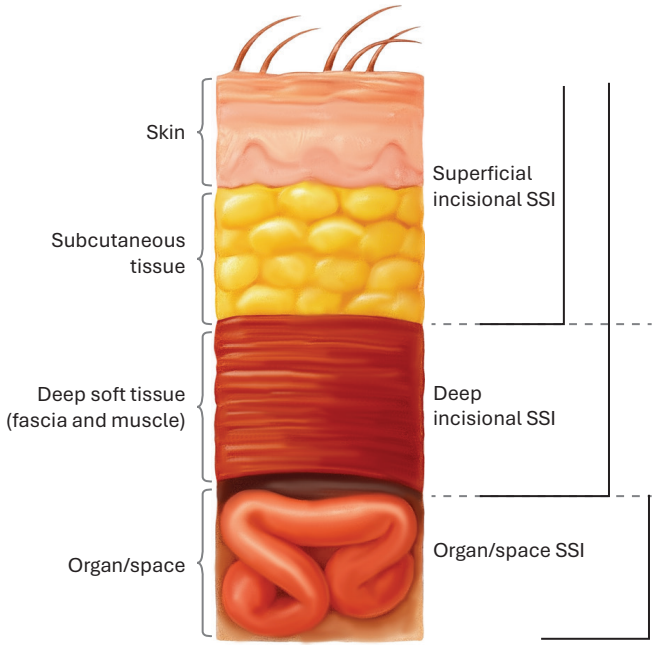

Fig 1: Classification of SSI by the Centers for Disease Control.

RISK FACTORS (BOX 1)

Surgical site infections are one of the most common reasons for unplanned readmission after surgery. SSIs occur in 1%–3% of patients undergoing inpatient surgery, depending on the type of procedure performed.[4] Surgical site infection rates in low-to middle-income countries may be higher than those in other countries, possibly due to cumulative resource limitations and risk factors. SSI rates differ as per surgery. Abdominal surgery, particularly colon surgery, is associated with the highest SSI rates, whereas eye surgery is associated with a very low rate. SSIs following some cardiac surgeries and other surgeries that use implanted materials, such as joint replacement and hernia repairs with mesh, are less common, but if an SSI occurs, it can have significant consequences. Emergency surgical procedures usually have higher SSI rates than planned elective procedures.

Risk Assessment

There is a complex interaction between various factors when an SSI occurs, including antimicrobial prophylaxis, the nature and number of organisms contaminating the surgical site, the technique of the surgeon, and the health of the patient (Box 1).

Table 1: Surgical site infection definitions.[3]

	Time to event	Extent of tissue involvement	Clinical features	Criteria for diagnosis
Superficial incisional SSI	Within 30 days of the NHSN procedure	Skin and subcutaneous tissue	• Peri-incisional pain or tenderness • Localized peri-incisional swelling • Peri-incisional erythema or heat	• At least one clinical feature AND at least one of the following: • Purulent drainage from the superficial incision • Organisms are identified by culture (or non-culture-based microbiologic testing method) performed for clinical diagnosis or treatment (e.g., not surveillance) • Incision opened by the surgeon (or other designated clinician) because of concern for superficial SSI
Deep incisional SSI	Within 30 or 90 days of the NHSN procedure	Deep soft tissues of the incision, such as the fascia and muscle layers	• Fever (>38°C) • Localized pain or tenderness	• Purulent drainage from the deep incision • Deep incision that spontaneously dehisces or is opened by the surgeon (or other designated clinician) because of concern for deep SSI, AND organisms are identified by culture (or non-culture-based microbiologic testing method) performed for clinical diagnosis or treatment (e.g., not surveillance). Presence of at least one clinical feature, in the absence of microbiologic testing
Organ/space SSI	Within 30 or 90 days of the NHSN procedure	Any part of the body deeper than the fascia/muscle layers that was opened or manipulated during the procedure	Clinical features for specific organs/spaces can be found at the CDC website As an example, for intra-abdominal infection, at least two of the following: • Fever (>38°C) • Hypotension • Nausea, vomiting • Abdominal pain or tenderness • Elevated transaminases • Jaundice	Appropriate clinical features specific to the organ/space AND at least one of the following: • Purulent drainage from a drain placed into the organ/space • Organisms identified from the culture of fluid or tissue obtained from a superficial incision • Abscess or other evidence of infection involving the organ/space detected on gross anatomical examination or histopathologic examination • Radiographic imaging findings suggestive of infection

Box 1: Patient and operation characteristics that may influence the risk of SSI development.[5,6]

Patient
- Age
- Nutritional status
- Diabetes
- Smoking
- Obesity
- Coexistent infections at a remote body site
- Colonization with microorganisms
- Altered immune response
- Length of preoperative stay

Operation
- Duration of surgical scrub
- Skin antisepsis
- Preoperative shaving
- Preoperative skin prep
- Duration of operation
- Antimicrobial prophylaxis
- Operating room ventilation
- Inadequate sterilization of instruments
- Foreign material in the surgical site
- Surgical drains
- Surgical technique
- Poor hemostasis
- Failure to obliterate dead space
- Tissue trauma

SURGICAL WOUND CLASSIFICATION

One of the most important risk factors for SSI is the degree of contamination of a surgical wound at the time of the operation, which can be divided using the National Healthcare Safety Network (NHSN) wound class as clean, clean-contaminated, contaminated, or dirty/infected (Box 2).[4]

MICROBIOLOGY

The significant organisms causing SSIs after clean procedures are skin flora, including *Staphylococcus aureus, Streptococcal* species, and coagulase-negative *Staphylococci*. In clean-contaminated procedures, the main organisms include enterococci and gram-negative bacteria, in addition to skin

Box 2: Surgical wound classification.[7]

- **Class I (clean):** These are uninfected surgical wounds where no inflammation is present and there is no entry into the respiratory, gastrointestinal, genital, or uninfected urinary tracts. Such wounds are closed primarily and, if drainage is required, it is achieved using a closed system. Incisions following blunt (nonpenetrating) trauma may also be classified here if the criteria are satisfied
- **Class II (clean-contaminated):** This category includes operative wounds where the respiratory, gastrointestinal, genital, or urinary tracts are entered in a controlled manner, without unusual contamination. Procedures involving the biliary tract, appendix, vagina, or oropharynx fall into this group, provided there is no active infection and no major technical break
- **Class III (contaminated):** This group includes open, recent traumatic wounds, as well as operations with significant breaks in sterile technique (such as open cardiac massage), gross spillage from the gastrointestinal tract, or surgical incisions where acute but nonpurulent inflammation is encountered
- **Class IV (dirty-infected):** These are old traumatic wounds containing devitalized tissue or those associated with existing clinical infection or perforated viscera. In this class, the microorganisms responsible for postoperative infection are presumed to have been present in the operative site prior to surgery

flora. When the surgical procedure involves a viscus, the microorganisms are the endogenous flora of the viscus or nearby mucosal surface.

CLINICAL FEATURES

When there is a clinical suspicion of SSI, the wound should be examined directly to facilitate tactile and visual inspection (Table 1).

Superficial SSI

The skin surrounding the wound should be evaluated, including documentation of the presence and extent of erythema and induration (edema). The usual symptoms of superficial SSI are localized swelling, drainage with or without odor, warmth, wound breakdown and separation (i.e., dehiscence), pain at the incision site, and peri-incisional erythema. The presence of surrounding erythema and/or purulence typically distinguishes infected from uninfected dehiscence. In the absence of pus or redness, culturing deep tissue is usually helpful; however, care must be taken to avoid contaminating the culture with skin flora.

Deep Incisional SSI

The pathognomonic feature of deep incisional SSI is the involvement of the fascia and/or muscle. Symptoms of a deep SSI may include localized swelling, drainage with or without odor, wound breakdown, warmth and separation (i.e., dehiscence), pain at the incisional site, and peri-incisional erythema. Tenderness or fluctuant masses may be palpated in the wound area. Deep SSIs are typically associated with fever and local tenderness. Systemic signs of infection, such as fever, leukocytosis, or elevation of other markers of acute inflammation, such as C-reactive protein or procalcitonin, are usually associated with it. To facilitate inspection and debridement if needed, exploration and inspection of the wound with suspected deep SSI are often performed in the operating theatre.

Organ/space SSI

Patients with organ/space infection usually have fever, malaise, and pain/tenderness in the body region where their operation was performed, with or without overlying skin changes. Diagnosis of organ/space SSI is usually made after an imaging study demonstrates an abscess in the cavity or if any organs are involved in the prior operation. Gram staining and culture methods of the drainage (percutaneous and surgical) usually confirm the infection.

DIFFERENTIAL DIAGNOSES

The differential diagnoses that can be considered are:

- Stitch abscess
- Hematoma
- Seroma.

DIAGNOSIS

The diagnosis of SSI is usually clinical. A thorough examination of the skin surrounding the surgical site is required to evaluate the presence and extent of edema, erythema, induration, or any drainage.

Imaging

Ultrasound is an easily available imaging technique that can identify the presence of fluid in the subcutaneous tissues. However, in the cases of deep or organ space SSIs, CT or MRI imaging can result in a more detailed evaluation of the underlying soft tissue and organ space.

Cultures

Gram staining and culture should be performed in cases of wound opening or any suspected SSI to identify the causative organisms. It is recommended to collect cultures

with a swab directly from the specific site of infection in the open wound.

Diagnosis According to the Type of Infection

Superficial SSI

In patients with clinical signs of superficial SSI (e.g., localized swelling, warmth, or drainage) or wound separation, additional imaging tests are generally unnecessary.

Deep Incisional SSI

In patients with clinical signs of deep SSI, similar to superficial SSI, imaging (e.g., ultrasound, computed tomography) can be helpful in estimating the extent and depth of infection to guide the approach to source control.

Organ/space SSI

In patients with clinical signs of organ/space infection (e.g., malaise, fever, and pain/tenderness), imaging is essential to identify abscesses or fluid collections in the operated region. Diagnosis is ascertained through positive cultures of fluid obtained during a drainage procedure (percutaneous or surgical), which helps in antimicrobial therapy.

MANAGEMENT

The treatment of superficial SSI involves wound exploration and debridement. Antibiotics are needed in the setting of surrounding skin erythema, deeper soft tissue infection, or any evidence of systemic signs and symptoms of infection. Deep SSI treatment requires antibiotic administration and wound exploration/debridement.

Empiric Therapy

Depending on the most likely organisms for a wound, Gram staining, wound class, prior antibiotics, and antibiotic resistance patterns, empirical treatment is decided. The duration of treatment depends on the clinical response. Antibiotics are started under the following clinical circumstances:[8,9]

- Associated cellulitis
- Cellulitis associated with an intact but indurated surgical incision (even when no wound drainage or subcutaneous fluid collection)
- Cellulitis persisted in the surrounding skin after the wound opening
- Persistent inflammation after debridement or drainage (i.e., source control not achieved) in subcutaneous or deeper tissues
- Implanted materials (e.g., orthopedic hardware mesh and vascular grafts) are present in the infected area
- Systemic signs of infection are present (e.g., temperature ≥38°C, leukocytosis)
- Septic shock was present despite the source control.

The choice of antibiotics is based on the wound class, initial Gram staining, prior exposure to antibiotics, history of colonization with antibiotic-resistant organisms (e.g., methicillin-resistant *Staphylococcus aureus*), and local antimicrobial resistance patterns. The most common organisms isolated from SSI are *Staphylococcus aureus*, coagulase-negative staphylococci, *Streptococcus* spp., and *Enterococcus* spp.[10] In cases of traumatic abdominal injury or gastrointestinal tract perforation, antibiotics are administered against Gram-negative rods and anaerobic organisms, as well as typical gram-positive skin organisms.

If no foreign material is retained, antibiotics should be stopped with the resolution of cellulitis and/or normalization of physiological parameters, such as a raised WBC count. A short course of antibiotics (24–48 hours) is preferred for limited cellulitis.[11] In the case of intra-abdominal organ/space infection, antimicrobial treatment can be stopped four days after source control is achieved. There is no evidence to guide the appropriate duration of antimicrobial therapy for complicated SSI. Antimicrobial treatment, wound exploration, and debridement should be strongly considered if infection worsens within 24 hours of initiation of treatment, as necrotizing soft tissue infection can develop.

Wound Care and Closure

Serial debridement is suggested for wounds that have been opened due to SSI and are often left to heal by secondary intention; however, at times, delayed primary closure may be performed. The choice of method generally depends on the severity of the infection, location of the surgical incision, amount of tissue loss, and extent of required debridement, with handling of any implanted materials. It is often difficult to differentiate an abscess from an anastomotic leak in abdominal organ/space SSI. The NHSN definitions include anastomotic leak as an organ/space SSI; however, not all colectomy or post-enteric abscesses are due to anastomotic leaks.

Negative Pressure Wound Therapy or Vacuum-assisted Wound Closure

Negative pressure wound therapy (NPT) is an alternative to wound healing by secondary intention with wound packing. For open wounds with a clean, granulating base, NPT can be performed by reducing excess fluid accumulation and gradually decreasing the size of the wound. NPT also protects the patient's skin from frequent and regular dressing changes.

Definitive Treatment

Clinical response of the patient, results of wound culture, and sensitivities determine definitive therapy. For wounds with significant tissue loss from debridement or loss of domain

from skin contraction, skin grafting or flap reconstruction is necessary. For SSI with implanted materials, the risk of incomplete SSI treatment must be considered against the risks associated with the removal of the implanted materials. There can be disease progression and further deterioration of the surgical site, implanted materials are not removed, and intravenous antibiotics are given.

PREVENTION OF SSI (TABLE 2)

Surgical site infections can be prevented using measures that include timely administration of prophylactic antibiotics, avoiding elective surgery in patients with active infection, maintenance of sterile conditions, and proper skin preparation.[13]

Infection Control

Important factors for the prevention of SSI are:

- Careful attention should be paid to other perioperative control measures
- Timely administration of effective preoperative antibiotics
- Measures by operating staff include hand hygiene and use of gloves and other barrier devices (masks, caps, gowns, drapes)
- Application of antiseptics to the skin is advised to reduce the burden of skin flora .

Timing of Surgery

It is essential that complete treatment for the infection is performed prior to surgery, especially in elective surgeries, particularly in circumstances when placement of prosthetic material is expected. In cases where emergency surgery is required, the risk of infection must be assessed based on the timing of surgical intervention on a case-by-case basis.

Staphylococcus aureus Decolonization

Universal *Staphylococcus aureus* screening and decolonization remain controversial and uncertain. *Staphylococcus aureus* decolonization in preop may be reasonable for surgical patients known to be nasal

Table 2: Selected risk factors for and recommendations to prevent SSI.[12]

Risk factor	Recommendation
Intrinsic, patient-related (preoperative)	
Unmodifiable	
Age	No formal recommendation; higher risk may reflect comorbidities or immunosenescence
History of skin/soft-tissue infections	No formal recommendation; may indicate inherent host immune differences
Modifiable	
Glucose control	Maintain serum glucose control in all surgical patients, including non-diabetics
Obesity	Increase prophylactic antimicrobial dose in morbidly obese patients
Smoking	Encourage cessation ≥30 days before surgery
Hypoalbuminemia	No formal recommendation; although a risk factor, do not delay surgery for total parenteral nutrition
Preparation of patient	
Hair removal	Only if hair interferes with surgery; remove outside OR with clippers/depilatory. Avoid razors
Preoperative infections	Identify and treat infections at distant sites before elective surgery. Do not test/treat asymptomatic bacteriuria except in urologic procedures
Operative characteristics	
Surgical scrub	Perform with appropriate antiseptic; scrub hands/forearms for 2–5 minutes
Skin preparation	Clean incision site; use dual-agent prep with alcohol (unless contraindicated)
Antimicrobial prophylaxis	Use only when indicated; select agent per procedure. Administer ≤1 hr before incision; discontinue after closure
Blood transfusion	Minimize blood loss/transfusions, as transfusion may impair macrophage function and increase SSI risk
Operating room characteristics	
Ventilation	Follow American Institute of Architects' recommendations for OR air handling
Normothermia	Maintain perioperative normothermia (>35.5°C) for non-hypothermia procedures
Traffic	Limit OR traffic
Sterilization of equipment	Sterilize all surgical instruments per manufacturer's validated parameters

carriers of *Staphylococcus aureus*. For patients at high risk of negative outcomes if *Staphylococcus aureus* infection develops at the surgical site (e.g., orthopedic procedures with hardware implantation, cardiothoracic surgery, and immunosuppressed patients), decolonization can be advised. Universal decolonization of these patients is favored to avoid the pitfalls of screening in many cases, but it depends on hospital policy and specific cases.

Surgical Technique

In clean-contaminated, contaminated, and dirty abdominal procedures, wound protectors reduce the risk of SSI. Measures such as effective hemostasis, gentle traction, obliteration of dead space, removal of devitalized tissues, irrigation of tissues with saline to avoid excessive drying, minimizing the duration of closed-suction drainage, and wound closure without tension are useful. Inadequate data are available to support the routine use of drains for SSI prevention. Laparoscopic-assisted procedures and minimally invasive surgeries are usually associated with lower SSI rates than open surgeries.

Other Interventions

Other considerations are:

- Normothermia in the preoperative period is better than hypothermia for reducing the risk of SSI
- Supplemental oxygen perioperatively is also associated with decreased SSI rates
- Laminar airflow and routine preoperative hair removal have limited evidence for reducing SSI
- Any particular wound dressing over a closed surgical wound has not shown any benefit in reducing the rate of SSI.[14]

ANTIMICROBIAL PROPHYLAXIS

The aim of antimicrobial prophylaxis is to reduce the burden of microorganisms at the surgical site during surgery, thereby decreasing the SSI rate.

Choosing an Agent

The choice of an antimicrobial for SSI prophylaxis is based on pharmacokinetic profile, safety, cost, and antimicrobial activity. It is a misconception that broad-spectrum antimicrobial agents result in lower rates of SSI than narrow-spectrum antimicrobial agents. An example of antimicrobial prophylaxis is presented in table 3. For further details on antimicrobial prophylaxis as per surgery type, refer to CDC/NHSN guidelines.[4]

Preferred Agent for Usual Surgeries

Cefazolin is the usual choice for many surgeries. It has the following advantages:

- A desirable spectrum of activity against organisms commonly encountered in surgery
- Good safety
- Desirable duration of action
- Low cost.

For obese patients, doubling the normal dose of cephalosporins may produce similar concentrations to those achieved with standard doses in nonobese patients. Hence, the administration of cefazolin 2 g for patients weighing <120 kg and cefazolin 3 g for patients weighing ≥120 kg is suggested.

Timing of Prophylaxis

Surgical antimicrobial therapy should be administered within 60 minutes before the surgical incision to ensure adequate drug tissue levels at the time of the initial incision. In the case of vancomycin or ciprofloxacin, administration is recommended to begin 120 minutes before the surgical incision because of the prolonged infusion times required for these drugs.

Duration

Repeat intraoperative dosing is suggested for procedures that exceed two half-lives of the drug to maintain adequate antimicrobial serum and tissue concentrations, especially for surgeries in which there is excessive blood loss (>1500 mL) or prolonged surgeries. In the case of factors that shorten the antimicrobial half-life, such as extensive burns, redosing is advised. The dosing interval should be measured from the time of the preoperative dose (not from the beginning of the procedure). As a rule, repeated antimicrobial dosing

Table 3: Antimicrobial prophylaxis for cardiac surgery in adults.[15,16]

Nature of operation	Common pathogens	Recommended antimicrobials	Usual adult dose	Re-dose interval
Cardiac procedures: Coronary artery bypass, cardiac device insertion procedures (e.g., pacemaker implantation), placement of ventricular assist devices	*Staphylococcus aureus*, *Staphylococcus epidermidis*	Cefazolin	<120 kg: 2 g IV ≥120 kg: 3 g IV	4 hours
		OR Cefuroxime	1.5 g IV	4 hours
		OR Vancomycin	15 mg/kg IV (max 2 g)	N/A
		OR Clindamycin	900 mg IV	6 hours

following wound closure is not necessary and may increase antimicrobial resistance.

CONCLUSION

Surgical site infections are a significant complication of surgery that impacts patients and leads to increased hospital stays and healthcare costs. Preventive strategies include steps like adequate skin preparation, the use of prophylactic antibiotics, maintaining normal body temperature during surgery, and meticulous wound care. Treatment typically involves antibiotics and may also necessitate opening and cleansing the wound, excising infected tissue (debridement), and draining any abscesses.

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